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A CONTRIBUTION TO THE TAXONOMY OF TANYTARSINI (DIPTERA: CHIRONOMIDAE) OF SUB-SAHARAN AFRICA, WITH A DESCRIPTION OF A NEW GENUS (*AFROZAVRELIA*) AND FIVE NEW SPECIES FROM OTHER GENERA

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ABSTRACT

A brief overview is given of existing knowledge of the systematics of Tanytarsini in sub-Saharan Africa. A new genus, *Afrozavrelia*, is established for *Zavrelia kribiensis* Kieffer and five new species (*Rheotanytarsus shebelensis, Tanytarsus awashensis, Tanytarsus flumineus, Tanytarsus zimbabwensis* and *Virgatanytarsus aboensis)* are also described. An additional note, on the diagnostic features of the larvae and pupae of two other species (*Rheotanytarsus fuscus* Freeman and *Rheotanytarsus montanus* Lehmann) and the pupa of *Rheotanytarsus guineensis* Kieffer, is also provided.

Key words: Chironomidae, Tanytarsini, Ethiopia, Zimbabwe, South Africa, new genus, new species, Diptera, systematics.

INTRODUCTION

There are a number of reliable publications on the systematics of the tribe Tanytarsini (Diptera, Chironomidae) in Africa south of the Sahara: Freeman (1958) described new species and revised the work of earlier taxonomists, Kieffer and Goetghebuer. Kyerematen & Sæther (2000) reviewed the Afrotropical *Rheotanytarsus,* and Ekrem (2001) reviewed the Afrotropical *Tanytarsus*. All these authors included useful keys in their publications.

This does not exclude the likelihood that there are not more Tanytarsini to be described from the region, especially those of the mountain chain that extends from South Africa to Ethiopia in the north (see Ekrem 2001). This paper describes five new species from this mountain chain or its foothills and also sets up a new genus, *Afrozavrelia*, for *Zavrelia kribiensis* Kieffer, a species that does not fit into the genus *Zavrelia* Kieffer in any life stage.

The descriptions of taxa in this paper are based on studies of museum collections, from specimens collected from Ethiopia, Zimbabwe, and South Africa (see 'Methods' for further details).

THE TANYTARSINI IN SUB-SAHARAN AFRICA

The 64 sub-Saharan Tanytarsini previously described by various authors can divided into two categories: 62 species in recognized or newly-described genera, and two species that cannot be placed in known genera. These are discussed below, together with references to source publications and short notes on the diagnostic features of some species.

Species in recognized or newly-described genera

Tanytarsus: 26 species (Ekrem 2001).

Rheotanytarsus: 19 species (Kyerematen & Sæther 2000).

Cladotanytarsus: 10 species. One species (*C. crebus)* described by Lehmann (1981); six species described by Freeman & Cranston (1980); three species–*C. irsacus, 'Tanytarsus' bukavus* and *'Tanytarsus' congolensis* – described by Lehmann (1979). (*Note:* Ekrem (1999) transferred *T. bukavus* and *T. congolensis* to *Cladotanytarsus.*)

Niduurbia: one species, *N. capicola,* described by Säwedal (1982). This was originally placed in *Micropsectra* by Freeman (1958).

Stempellina. Two species: *S. chambiensis* Goetghebuer in Freeman (1958); *S. reissi* described by Lehmann (1981).

Stempellinella: one species. Although Freeman (1958) described *'S. truncata'* as a species of *Stempellina,* this species fits more closely into the genus *Stempellinella* Brundin as it has a number of features more characteristic of the latter genus: in the adult male the anal point has longitudinal crests extending onto the anal tergite with basal spinules between; the pupa has a shagreen pattern similar to that of *Stempellinella brevis* (Edwards) (Pinder & Reiss 1986) and segment VIII has a single, robust sclerotized postlateral spine; the larval antenna is, however, of the *Constempellina*-type with both Lauterborn organs being distal on segment 3 and a pedestal with a prominent apical spur. (This description based on pupa, a pharate male and larval head capsule from the same sand grain case, Cat. ABLLR 9J, in AM).

Friederia villosa Sæther & Andersen (Sæther & Andersen 1998).

Virgatanytarsus – three species; *V. arduennensis* (Goetghebeur) (= *subreflexens* Freeman), *V. nigricornis* (Goetghebeur) (see Freeman 1958) and *V. aboensis,* described in this paper.

Zavrelia kribiensis Kieffer (=*Afrozavrelia* sp.): one

species. In this paper this species is placed in a new genus, *Afrozavrelia.*

Species that cannot be placed in known genera

'Tanytarsus' abnormis' (Lehrmann, 1981)
Characteristic features: hairy eyes with no dorsal extension, superior volsella with digitus but no median volsella.

'Tanytarsus' saetosus (Lehrmann, 1981)
Characteristic features: hairy eyes with no dorsal extension; costa ending well proximal to M_{3+4}; anal point bare with a small knob-shaped 'point', but superior volsella and median volsella of *Tanytarsus*-type.

METHODS

Ethiopian specimens were collected by the author while working in the cooperative programme described in the Acknowledgements. The Zimbabwean material was collected by the author working in the Zoology Department, University of Zimbabwe (then Rhodesia) financed by the Rockefeller Foundation of New York. Specimens from the Western Cape Province were collected by the author or by members of the Freshwater Research Unit, Zoology Department, University of Cape Town; the rest of the South African material was collected by Dr F. C. de Moor and his team at the Albany Museum, Grahamstown, Eastern Cape.

Pinned specimens were treated as follows: the wings were removed from the dried specimen and mounted directly in Canada balsam, then the rest of the specimen was macerated in 5% potassium hydroxide at room temperature for 24 hours; the KOH was removed by placing it in 70% alcohol for about 10 minutes, and then into 96% alcohol. It was then dissected and mounted in Canada balsam–dissolved in cellosolve–on the same slide as the wings. Specimens preserved in alcohol were dissected and mounted in the same type of balsam. Drawings were made by means of a drawing tube on a compound microscope. Measurements were made with an eyepiece micrometer in the compound microscope. Morphological terminology is according to Sæther (1980) and the description of the males follows the style of Cranston, Dillon, Pinder & Reiss (1989), using their generic definitions. The descriptions of females follows the style of Sæther (1977).

The holotypes and paratypes of all the species described here and other material used in the descriptions have been deposited in the Zoologische Staatssammlung, Munich, Germany (ZSM) or in the Albany Museum, Grahamstown, 6140, Eastern Cape Province, South Africa (AM). The catalogue numbers of the specimens are given in the text.

Abbreviations

AR antennal ratio. Ratio of length of apical flagellomere to combined length of basal flagellomeres.
LR leg ratio. Ratio of length of tarsomere 1 to length of tibia.
SV 'Schenkel-Schiene Verhältnis': Ratio of femur plus tibia to tarsomere 1.
BV 'Beinverhältnisse'. Combined length of femur, tibia and tarsomere 1 divided by length of tarsomeres 2 to 5.
ADH A D Harrison (Collector).

TAXONOMIC DESCRIPTIONS

Afrozavrelia gen. nov.

Generic diagnosis

ADULT MALE
Size: small, wing length about 1 mm.
Head: antenna with 10 flagellomeres; no frontal tubercles; eyes hairy with long dorso-medial extensions; palps normal, segment 3 with no subapical sensilla.
Thorax: with antepronotal lobes widely separated overreaching pronotum, no tubercle; acrostichals 22, biserial, dorsocentrals 18, partly biserial, prealars 2, supra-alar 1, scutellars uniserial. Wings densely clothed with setae, costa not produced, R_{4+5} ending before tip of M_{3+4}. Anal lobe not developed, squama bare.
Legs: fore tibia with short, straight spur, other tibia with small combs well separated each with a thin spur. Pulvilli absent.
Hypopygium: anal tergite bands weak not meeting centrally, about 12 anal tergite setae, anal point long, bare with rounded tip, superior volsella long with broad digitus, median volsella with few lamelliform setae and no simple setae, inferior volsella long extending up to, or beyond tip of gonostylus which is narrow with two long setae at tip.

ADULT FEMALE
(based on one pharate specimen)
Size: similar to male.
Head: general structure similar to male; antenna with five flagellomeres.
Thorax: similar to male. Wings and legs appear to be similar to male.
Genitalia: sternite VIII not forming a distinct floor under the anterior part of the vagina; gonocoxapodemes narrow and joined, gonopophysis of VIII simple, gonocoxite IX small with two setae, coxosternapodemes very small and curved; segment X without setae, postgenital plate pointed, cerci small; seminal capsules oval with short necks, ducts convoluted joining to a central bulb with common opening.

PUPA

Size: small, in straight cases composed mainly of diatom frustules and detritus.

Cephalothorax: cephalic tubercles low and rounded, frontal setae flat, almost taeniate, no antepronotals or dorsocentrals, thoracic horn long, pointed and down-turned, no spinules, minutely rugulose, three precorneal setae small, short and flattened.

Abdomen: tergites I and II bare, II with a short hook row, III to VI with paired, elongate patches of points, simple S setae on segments II to IV, taeniate S setae on V to VIII; segment VIII with a few small spines at posterolateral corner; anal lobes with moderately developed fringe of taeniate setae; no pedes spurii.

LARVA

Size: small, in straight, portable cases consisting mainly of diatom frustules and detritus.

Head: with five-segmented antennae, of about 86% of head capsule length, on prominent pedestal, AR about 0.6, long basal segment with ring organ near base and seta subterminally, blade shorter that segment 2, accessory blade present, Lauterborn organs large, terminal on segment 2, sessile, style present. Labrum with SI palmate, bases fused, SII plumose on tall pedestal, SIII and IV seta-like, labral lamella well-developed, pecten epipharyngis consisting of three separate, slender distally pointed scales; premandible with two teeth and well-formed brush; mandible with dorsal tooth with three inner teeth, seta sub-dentalis long and curved, seta interna small and plumose, pecten mandibularis consisting of about 10 long lamellae. Mentum with median tooth rounded, six lateral teeth, the second being shorter then the first and third; ventromental plates fan-shaped, widely separated.

Body: anterior and posterior parapods with simple hooks, procercus with long anal and lateral setae.

NOTES

Afrozavrelia can be distinguished from *Neozavrelia* and *Zavrelia* in all life stages (Table 1). In some particulars – such as the anal point structure, the presence of a digitus, and the terminal Lauterborn organs – the former genus resembles *Neozavrelia*. In other particulars – such as the hairy eyes, the antennal tergite bands not meeting, and the more complete anal fringe of the pupa – it resembles *Zavrelia*. Nevertheless, in many other particulars – such as the strong dorsal extension of the eye, the very narrow gonostylus, the lack of a floor to the anterior vagina, the taeniate frontal setae of the pupa, the long antennae of the larva (especially

Table 1: Morphology of *Afrozavrelia* contrasted with that of *Neozavrelia* and *Zavrelia*

	Afrozavrelia	*Neozavrelia* Goetghebuer	*Zavrelia* Kieffer
MALE	Eyes hairy with long dorso-medial extension	Eyes bare or with short pubescence, no dorsomedial extension	Eyes hairy, no dorsomedial extension
	Front tubercles absent	Front tubercles absent	Small frontal tubercles
	Anal tergite bands weak, not meeting	Anal tergite bands fused, forming V-shape	Anal tergite bands not meeting
	Anal point bare dorsally	Anal point bare dorsally	Anal point with crests and spinules
	Digitus present	Digitus present	No digitus
	Median volsella with very few lamelliform setae	Median volsella with numerous setae, some slender	Median volsella with numerous setae, some simple
	Gonostylus very narrow	Gonostylus broad	Gonostylus broad
FEMALE	No floor under anterior vagina	Floor under anterior vagina (Cranston 1998)	Floor under anterior vagina
PUPA	Frontal setae taeniate	Frontal setae normal	Frontal setae normal
	Thoracic horn without spines or apical teeth	Thoracic horn without spines, with or without apical teeth	Thoracic horn with spines
	Posteriolateral comb weak, of a few small light teeth	Posterolateral comb strong, of numerous dark teeth	Posterolateral comb with single or double dark teeth
	Anal lobe with fringe of about 22 taeniae	Anal lobe fringe of 5-14 taeniae, or reduced	Anal lobe with fringe of 17-20 taeniae
LARVA	Antenna long, 86% length of head capsule, basal segment longer than flagellum	Antenna short, basal segment about as long as flagellum	Antenna short, basal segment about as long as the flagellum
	Lauterborn organs terminal and sessile	Lauterborn organs terminal and on pedicels	One Lauterborn organ sub-terminal, both on pedicels

the basal segment), and the short antennal blade – it resembles neither of the above two genera.

Sæther & Andersen (1998) describe another African member of the subtribe Zavreliina (that was erected by Sæther (1977)): *Friederia villosa* Sæther & Anderson, from Ghana. The genus *Friederia* differs very markedly from *Afrozavrelia*, however, as it has bare eyes, an anal point with setal tufts, superior volsella with no digitus, and median volsella reduced to a small tubercle with one, simple seta. The female and immatures are unknown.

Type species
Zavrelia kribiensis Kieffer.

Afrozavrelia kribiensis (Kieffer)
(Figs 1-13)

Zavrelia kribiensis Kieffer, 1923

Also described in Freeman (1958) and Freeman & Cranston (1980).

The description of the male, given above (in the generic diagnosis) and below, is more detailed than that of Freeman (1958) and the female, pupa and larva are also described. The female and immatures were associated from pupal cases with pharate males and females.

ADULT MALE (N = 4 mounted)
Body: length 1.1 mm.
Wing: length 0.9 mm; body colour very light brown, halteres dark tipped.
Head (Fig. 1): No frontal tubercles; antenna AR 0.6, 10 flagellomeres, eyes hairy with long dorsomedial extensions. Head setation: six inner verticals, two outer verticals, 30 clypeals. Length of palp segments, 15, 21, 24, 60, 111 µm; no subapical sensillae on segment 3.
Thorax. Setation: lateral antepronotals nil, acrostichals 22 biserial, dorsocentrals 18 biserial anteriorly, posterior prealars 2, supra-alar 1, scutellars 4 per side.
Wings (Fig. 2): broad, anal lobe not developed; densely clothed in setae; squama bare; R_{4+5} ending before tip of M_{3+4}, costa not extended.
Legs: fore tibia with short, straight spur, other tibia with small combs, well separated each with a thin spur; LR fore 1.5, mid 0.6, hind 0.7; SV fore 1.7, BV fore 2.5.
Hypopygium (Figs 3 & 4): anal tergite bands weak and not meeting, about 12 anal tergite setae, anal point long, bare with rounded tip, superior volsella long with broad digitus, median volsella (Fig. 4) with one, or possibly two, lamelliform setae, no simple setae, inferior volsella longer than the combined length of the gonocoxite and gonostylus; gonostylus narrow with two long setae at the tip.

ADULT FEMALE
(based on a pharate specimen, mounted).
Body: length 1.6 mm
Head: general structures as male, antenna with five flagellomeres.
Thorax. Setation: acrostichals 22 biserial, dorsocentrals 14, posterior prealars 2, supra-alar 1, scutellars 5 per side. Wings and legs appear to be similar to those of the male.
Genitalia (Figs 5 & 6): sternite VIII not forming a distinct floor under the anterior part of the vagina, gonocoxapodemes narrow, light, joined; gonopophysis simple but with ventrolateral enlargement; gonocoxite IX small with two setae; coxosternapodemes very small, light, curved; segment X without setae; postgenital plate pointed; cerci small, 27 µm; seminal capsules (Fig. 6) oval with short necks, 42 µm long, with neck; ducts convoluted joining to a central bulb and with a common opening.

PUPA (N = 5 mounted)
Remain in larval cases, made mainly of diatom frustules and detritus.
Exuviae: almost colourless, transparent.
Cephalothorax: cephalic tubercle low and rounded, frontal setae flat, almost taeniate; dorsum minutely pebbled; no antepronotals or dorsocentral setae; thoracic horn (Fig. 7) long, pointed and downturned, no spinules, minutely rugulose; precorneal setae small, short and flattened; wing sheath with nose.
Abdomen (Fig. 8): tergites I and II bare, II with short hook row of small rounded "hooks"; tergites III-VI with paired elongate patches of points; S setae (simple)– I none, II one, III and IV three; S setae (taeniate)–V, VI, VII four, VIII five; segment VIII with a few small spines at posterolateral corner (Fig. 8); no pedes spurii. Anal lobes moderately well developed with a complete fringe of about 22 taeniate setae per side.

LARVA
(N = 1 complete specimen, mounted; also based on five larval exuviae in pupal cases.)
The larva lives in a straight, portable case made mainly of diatom frustules and detritus.
Colour: yellowish.
Head: capsule 168 µm long, dorsal surface smooth. Antenna (Fig. 9) 144 µm long, with five segments on pedestal 84 µm high with a prominent apical spur. AR 0.6. Long basal segment with ring organ near base and seta subterminally, blade shorter than segment 2, accessory blade half the length of blade, both Lauterborn organs terminal, sessile almost as long as segment 3, style present, segment five fine and pointed.
Labrum (Fig. 10): SI palmate, bases fused, SII

plumose situated on tall pedestal, SIII and SIV seta-like; labral lamella well-developed; pecten epipharyngis consisting of three separate, slender, distally-pointed scales. Premandible (Fig. 11) with two teeth and well-formed brush.

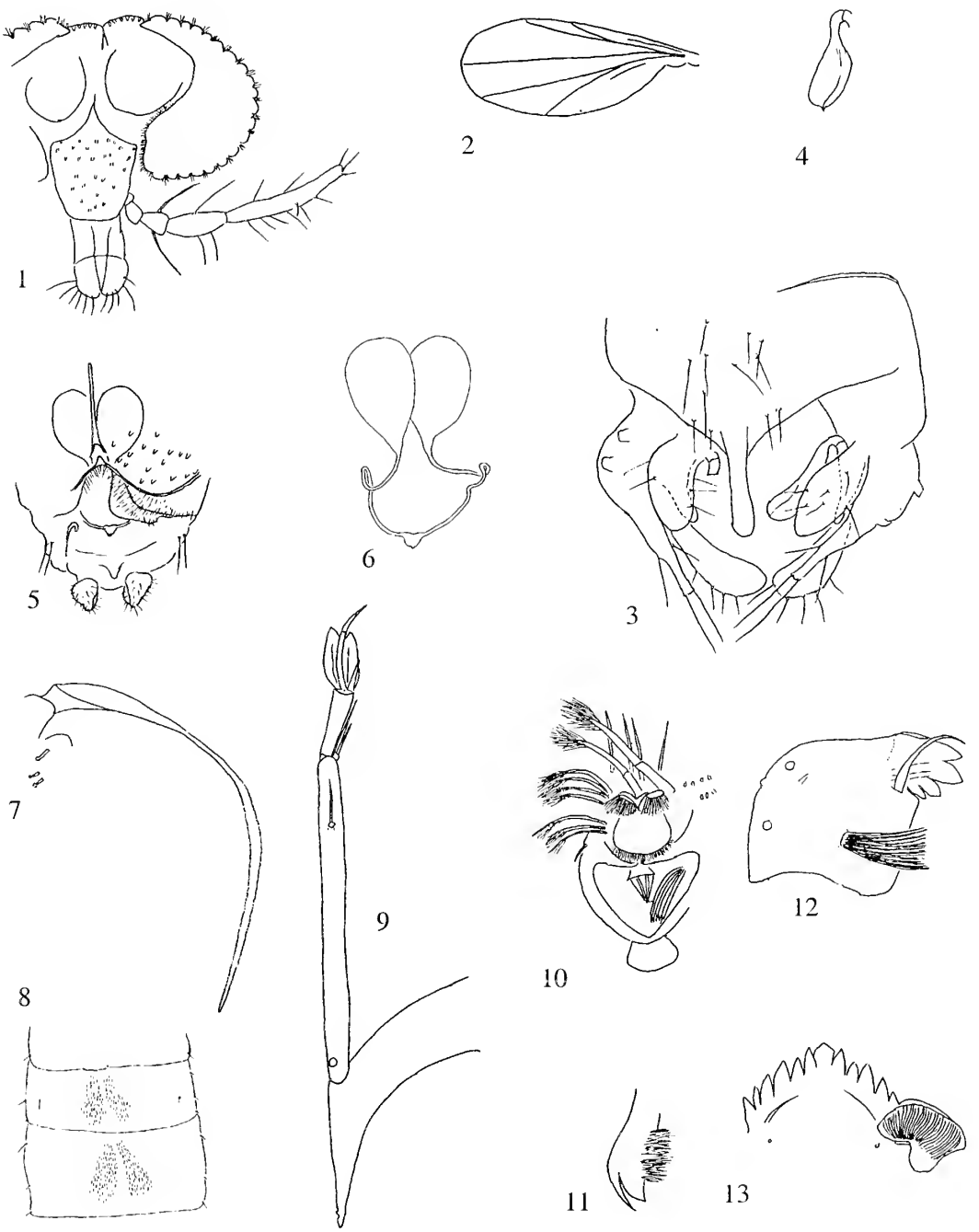
Mandible (Fig. 12): dorsal tooth light yellow, apical tooth and two inner teeth light brown; seta subdentalis long and curved, not extending beyond the apex; seta interna small and plumose; pecten mandibularis consisting of about 10 long lamellae.

Mentum (Fig. 13): all teeth light brown, median tooth rounded, six lateral teeth, second tooth shorter than the first tooth, then regularly decreasing in size; ventromental plates fan-shaped with anterior margin smooth and widely separated,

Body: anterior and posterior parapods with simple hooks; procercus broader than long with long anal and lateral setae.

SPECIMENS EXAMINED

All from Western Cape Province, South Africa, ♂, Molenaars River, 33^0 43'S 19^{0}10'E, 27 iv 96



Figs 1–13. *Afrozavrelia kribiensis*. **1-4**, adult male: 1, head; 2, wing; 3, hypopygium; 4, median volsella. **5-6**, adult female: 5, genitalia; 6, seminal capsules and ducts. 7-8, pupa: 7, thoracic horn and frontal setae; 8, abdominal tergites II–IV. **9-13**, larva: 9, antenna: 10, labrum; 11, premandible; 12, mandible; 13, mentum.

(cat. SAC.45R) (collector ADH) also 3 ♂♂, Eerste River, 33°56'S 19°10'E (Cat. E1Q2 24R, S2Q2 7M, S2Q2 10R) (collector Denise Schael, 1998); with 1 ♀ (Cat. RTDU.219), 2 pupae (Cat. RTDU. 282 with pharate ♂ and 148H with pharate ♀, cases contained larval remains, used for association), 3 larvae (Cat. RTDU, 294, 282 and 148H) (collector Rebecca Tharme, 1993-95). All material in AM.

NOTES

Habitat Preferences: The South African specimens were found in montane rivers with soft, unbuffered water. The larvae live in straight portable cases of diatoms and detritus and they appear to be detritivores or scrapers.

Distribution: Cameroon, Kribi; South Africa, Western Cape Province.

Rheotanytarsus shebelensis sp. nov.

(Figs 14-17)

ADULT MALE (N = 3 mounted)

Close to the generic definition in Cranston et al. (1989) except for the structure of the medium volsella that has no plate.

Body length: 1.92 mm.

Wing length: 1.3 mm.

Colour: Head and antennae brown; thorax and legs brown, vittae, preepisternum and postnotum dark brown; abdomen brown with no obvious markings.

Head: AR 0.43-0.47; palp segments: 24-30, 27-30, 60-63, 78-81, 144-150 μm; no subapical sensillae on palp segment 3. Head setation: temporals 7, clypeals 15.

Thorax: no scutal tubercle; setation: lateral antepronotals nil, dorsocentrals 9, posterior prealars 1, scutellars 4 per side.

Wings: most of the surface covered with setae. R_{2+3} absent. Setation of veins: R 22, R_1 26-29, R_{4+5} 50, seta also on other veins.

Legs: foretibia with short spur on scale; all combs with spurs. Leg measurements and ratios are given in Table 2.

Hypopygium (Figs 14, 15, 16, 17): anal tergite bands transverse or slightly V-shaped, not meeting; anal point without spine patches and downturned; superior volsella club-shaped without microtrichia (Fig. 14); median volsella (Fig. 16) with distal filamentous setae long extending beyond apex of inferior volsella, almost reaching the tip of the gonostylus, without median bend; distal setae narrow with no plate-like structure; inferior volsella normal, gonostylus tapering gradually. Figure 14 illustrates the Ethiopian specimen (the holotype) and Figs 15 & 16 a South African specimen with a narrower anal point and a somewhat smaller superior volsella. Some South African specimens have superior volsellae of intermediate size. Fig 17 illustrates the apodemes of the type.

SPECIMENS EXAMINED

1♂ found drowned, Wabe Shebele (river), Ethiopian Highlands, 07°01'N 39°03'E (ETC.34F) 1984.1.4, collector ADH (ZSM); 2 ♂♂ from light trap, Little Mooi River, KwaZulu-Natal, 29°13'S 29°53'E, (MOI 56CD & CH) and 2 ♂♂ from light trap, Kleinmooi River, KwaZulu-Natal, 29°13'S 29°53'E, 4.iv. 1995 (Cat. MOI. 65BT & CB), collectors F. C. de Moor and team (all in AM).

Holotype ♂ ETC. 34F; paratype ♂ MOI 65BT.

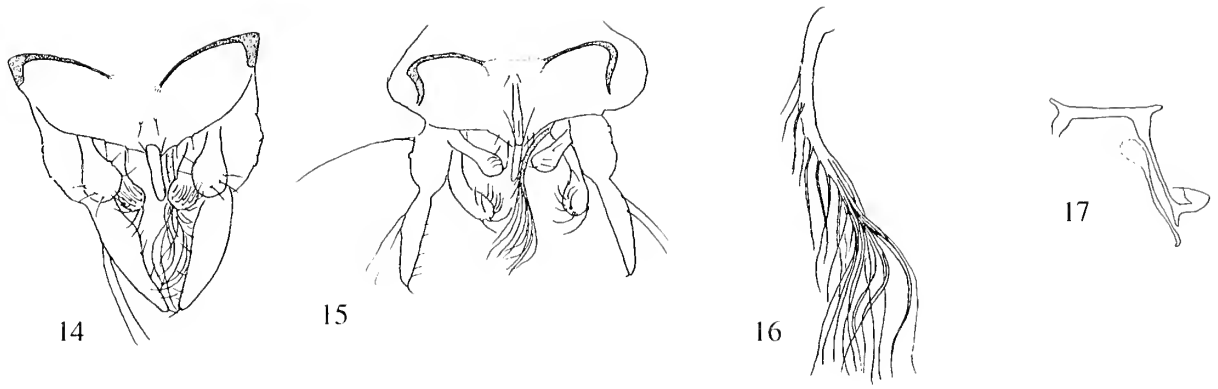
NOTES

This species falls into the *Rheotanytarsus pellucidus* group of Kyerematen et al. (2000) but it can be taken no further than couplet 3 of their key as it has filamentous not foliate setae on the median volsella. If this is neglected it would key out at couplet 5. It can be distinguished from the two species keyed there as follows: from *Rheotanytarsus pellucidus* (Walker) by not having the anal tergite bands clearly V-shaped, with the median volsella without

Table 2. *Rheotanytarsus shebelensis* leg measurements in μm and ratios

	fe	ti	ta_1	ta_2	ta_3	ta_4	ta_5	LR	BV	SV
p_1	528	288	588	324	240	168	98	2.0	1.7	1.4
p_2	540	420	204	132	84	72	48	0.5	2.9	4.7
p_3	600	504	300	204	168	120	72	0.6	2.5	3.7

Legend: fe = femur; ti= tibia; ta_1, ta_2, ta_3, ta_4, ta_5= tarsomeres 1-5; LR = leg ratio (length of tarsomere 1: length of tibia); BV = 'Beinverhältnisse' = combined length of femur, tibia and tarsomere 1 divided by length of tarsomeres 2 to 5; SV='Schenkel-Schiene Verhältnis' = ratio of femur plus tibia to tarsomere 1.



Figs 14-17. *Rheotanytarsus shebelensis*, adult male: 14, hypopygium (Ethiopian); 15, hypopygium (South African); 16, median volsella; 17, apodemes.

a median bend and lacking microtrichia on the superior volsella. It can be distinguished from *Rheotanytarsus buculicaudus* Kyerematen & Sæther by not having the anal tergite bands fused and with the gonostylus not abruptly but gradually narrowed (rather like that of *R. pellucidus*). In the key in Kyerematen and Sæther (2000) it keys to *R. buculicaudus* but differs from it as above.

Etymology: shebelensis referring to the Wabe Shebele (river) Ethiopian Highlands.

Habitat preferences: the larva has not yet been identified but it is assumed that, like most other members of the genus, it lives in the current in cases constructed for filter feeding. The adults were all collected drowned in or near rivers.

Distribution: Ethiopian Highlands and KwaZulu-Natal, South Africa.

Rheotanytarsus fuscus Freeman

(Figs 18-20).

Tanytarsus (Rheotanytarsus) fuscus Freeman 1954

Also described in Freeman (1958) and Freeman & Cranston (1980).

The adult male is described by Freeman (1954 & 1958) and the adult male and pupa by Kyerematen & Sæther (2000) but the pupal specimen used by the latter authors lacked the thoracic horn. Scott (1967) described the distinctive characteristics of the pupa and larva and also gave a detailed account of the biology and behaviour of this species. Certain features of the pupa and larva have not yet been described and are added here.

PUPA (N = 2 mounted)

Scott (1967) illustrated the cephalothorax from the lateral and dorsal view; showing no frontal setae and none could be detected on the specimens examined here. In lateral view the cephalic horn is shown to be of the usual *Rheotanytarsus* type with a broad base and a down-turned distal section bearing small points. One long precorneal seta extends as far as the bend of the cephalic horn as shown in Fig. 18 (one of the mounted specimens), the other two being very short. Figure 19 shows details of the pupal anal spur on VIII. Otherwise these specimens conform to the descriptions of Kyerematen & Sæther (2000) and Scott (1967).

LARVA

(Numerous mounted and unmounted specimens).

Body length: 2-4 mm, depending on trophic conditions.

Colour: Scott notes: "In life the head is bright reddish brown and the abdomen greenish. In alcohol the head is brown and the abdomen yellowish white."

Antenna: as per Scott, Lauterborn organs reach base of segment 5.

Labrum: similar to *R. curtistylus* Goetghebuer. Illustrated by Pinder & Reiss (1983).

Mandible: as per Scott (1967), all teeth are dark.

Mentum: all teeth are dark, width of ventromental plate 0.95 x width of mentum.

Maxilla (Fig. 20): the lacinal chaetae are well-developed, there is no pecten galearis and there are two setae maxillaris.

Body: Scott (1967) illustrated the posterolateral bifid setae on segments III to VI. One branch lies anteriorly, the other posteriorly, both are plumose and are about as long as one third of the segment. These are best seen on unmounted specimens as the mounting medium may make them transparent and difficult to see. The anal setae are long and dark brown and the anal papillae are short with rounded tips.

SPECIMENS EXAMINED

1 pupa: Cecilia Ravine, Table Mountain, 33°60'S 18°25'E, i.98 (cat. ABLCR.7T), collector Denise Schael; larvae from small waterfall,

Silvermine River, 34°05'S 18° 25'E (cat. SAC. 37K) 24 ix 95, collector ADH (all in AM).

NOTES

Habitat preference: stony torrents.

Distribution: in permanent mountain streams in southern Africa.

Rheotanytarsus guineensis Kieffer

(Figs 21-25)

Rheotanytarsus guineensis Kieffer, 1918

Tanytarsus (Rheotanytarsus) guineensis Freeman, 1958

Also described in Freeman & Cranston (1980) and Kyerematen & Sæther (2000).

The male hypopygium is described by Freeman (1958) and the hypopygium, female genitalia and pupa are described by Kyerematen & Sæther (2000). More details of the pupa and a description of the larva are given here. One larva was taken from a pupal case with pupa containing pharate male.

PUPA (N=2, mounted)

Cephalothorax: surface finely rugose, two minute pairs of dorsocentral setae, thoracic horn and precorneal setae as in Fig. 21, horn downturned, very transparent with minute small points on distal half, discernable under high power magnification; precorneal setae also very transparent, one long and two short.

Abdomen: paired spine patches on tergites II-IV, as per Keyermaten & Sæther; anal spur (Fig. 22) simple.

LARVA (N=6 mounted)

Colour: greenish in life; length *c*. 4 mm.

Head capsule: light brown; length 312 µm.

Antenna (Fig. 23): length 120 µm, AR 0.4; Lauterborn organs reach base of segment 5.

Labrum: similar to that of *R. curtistylus* Goetghebuer (Pinder & Reiss 1983).

Mandible (Fig. 24): all teeth dark brown, similar to the generic definition (Pinder & Reiss 1983) including the large seta interna consisting of four plumose branches.

Mentum: all teeth dark brown, width of ventromental plate 0.91 x width of mentum, specimen somewhat flattened on slide.

Maxilla (Fig 25): similar to that of *R. fuscus* but differing in small details such as the shape of the lacinal chaetae,

Body: claws of parapods all simple; procercal setae long and dark; anal tubules short with rounded tips. Bifid posterolateral setae are present on at least some of the middle segments. These are plumose but transparent and difficult to discern on mounted specimens.

SPECIMENS EXAMINED

Two mounted pupae and one larva from the confluence of the Mpisini and Manzamnyama Rivers near Lake Mzingazi, 32°09'S 28°42'E(Cat. MpMan. 8/96 (1)) viii 96, collector Petra Vos, (all in AM).

NOTES

Habitat preference: running water; tolerates slower flow than some other species of the genus.

Distribution: tropical and sub-tropical Africa.

Rheotanytarsus montanus Lehmann

(Figs 26-33)

Rheotanytarsus montanus Lehmann, 1979

Also described in Kyerematen & Sæther (2000).

Lehmann (1979) described the adult male and the pupa; Kyerematen & Sæther (2000) described the adult male. The adults are dark brown to almost black flies, apparently more heavily chitinized and more compact than other African members of the genus. The species is found in upper mountain regions where streams are torrential. South African pupae and Ethiopian and South African larvae are described here.

PUPA (N = 4 mounted)

Colour: mostly colourless; abdominal spurs brown.

Cephalothorax: cephalic tubercles small with short frontal setae; thoracic horn (Fig. 26) long and slender, the distal, pointed third section more strongly chitinized than the rest and with a few small points; wing sheath with prominent nose; setae: two small antepronotals, three precorneals (Fig. 26), one much longer and darker than the other two; two pairs of small dorsocentrals, close together.

Abdomen (Fig. 27): no shagreen, tergites II-VI with anterior pair of point patches, very wide on II and III but width decreasing progressively so that those on V and VI are only as wide as long; patches of small spines just before and after hook row on tergite II; L setae very small or absent in some positions; three LS setae on V-VIII; fringe on anal lobe well developed; hook row on II small and undivided; pedes spurii A and B absent, but a few small transparent spines at the usual position of A on IV; posterolateral spur large with accessory points on ventral surface (Fig. 28).

LARVA (N = 16 mounted)

Head capsule: length 325 µm.

Colour: in fresh specimens the head and antennae glossy black, body greenish, claws light, and anal setae dark brown; in mounted specimens the head and antennae dark brown. Some South African specimens medium brown.

Head: dorsal surface, frontal apotome and labral

sclerites 1 and 2 all finely granular.

Antenna (Fig. 29): AR 2.6. Segment 2 very short, blade extends to tip of segment 3; Lauterborn organs prominent.

Labrum: similar to that of *R. curtistylus* Goetghebeur (Pinder & Reiss 1983). Premandible with two teeth and dense brush (Fig. 30).

Mandible (Fig. 31): all teeth brown, pecten mandibularis well-developed.

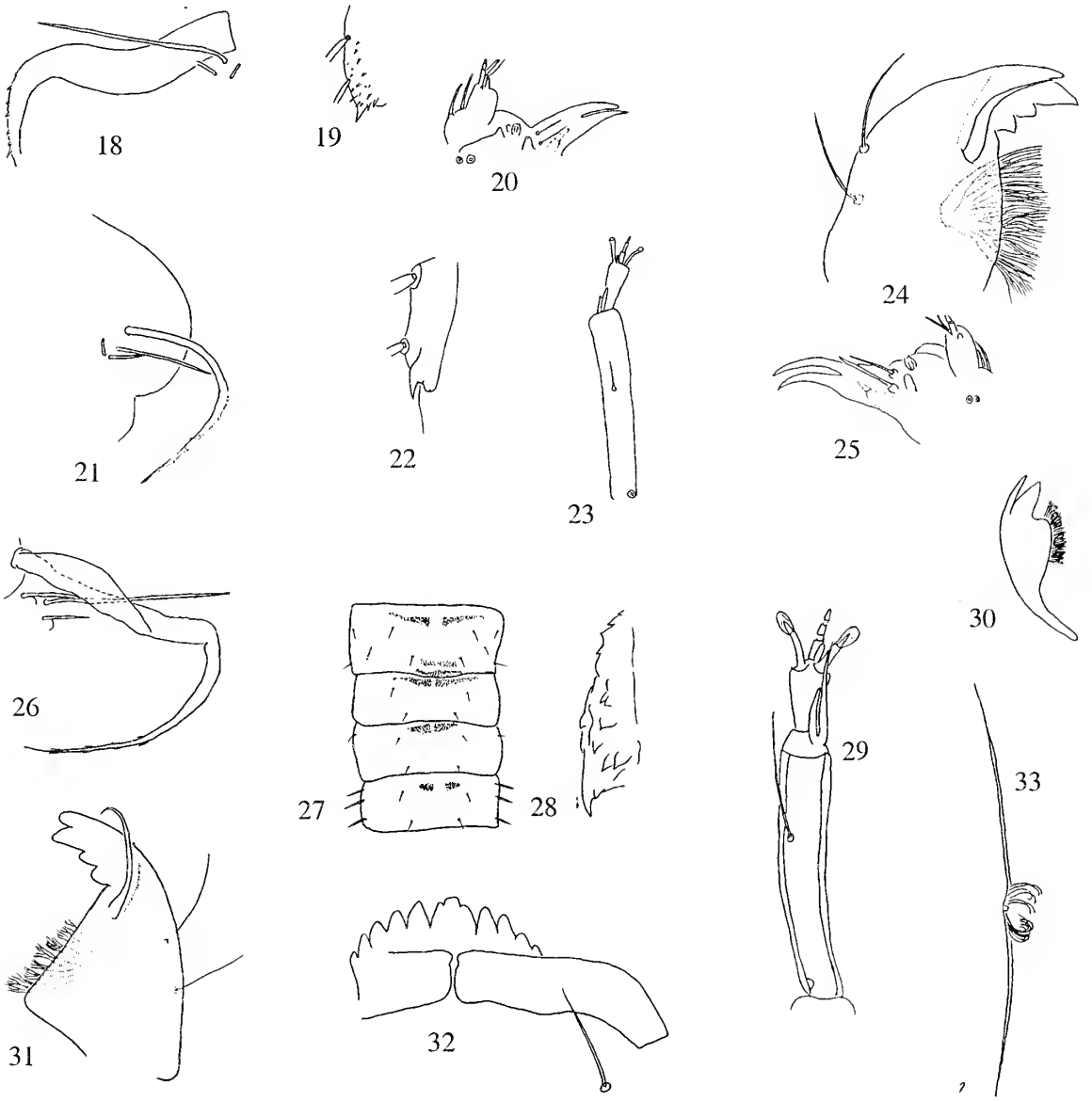
Mentum (Fig. 32): median tooth with lateral notches except in worn specimens, all teeth dark, width of ventromental plate the same as width of mentum.

Maxilla: very similar to that of *R. fuscus* (Fig. 20).

Body: apart from some simple setae, segments IV-VIII bear lateral setae with two main branches each bearing about six curved smaller branches (Fig. 33), in some cases the two main branches are adpressed so that the structure is not obvious; claws simple; anal tubules short with rounded tips.

SPECIMENS EXAMINED

Larvae from upper Kechene River, 09° 04'N 38°45'E (Ers. 6K), 13 ix 83; Danka River, 07°05'N 39°46'E (Ers. 34F), 20 i 84, collector ADH (in ZSM); South African specimens: from the Eastern Cape Province, one larva from KuKowa Stream, tributary of Slang-Mbashe River, (ECR 52) 7. xii 90; numerous larvae and four pupae from the Wildebees River near Glenelg, 31°13'S 28°04'E (ECR 112C 1 & 2) 26 iii 93; from KwaZulu-Natal, one larva from Bushmans River above Tugela confluence, 28°46'S 30°10'E (Bus 57Z (2) 05 x 2000. Collectors F.C. de Moor and team (in AM).



Figs 18-33. *Rheotanytarsus* spp.: **18-20**, *R. fuscus*. 18-19, pupa: 18, thoracic horn and frontal setae; 19, anal spur on VIII. 20, larva, maxilla. **21-25**, *R. guineensis*. 21-22, pupa: 21, thoracic horn and frontal setae; 22, anal spur on VIII. 23-25, larva: 23, antenna; 24, mandible; 25, maxilla. **26–33**, *R. montanus*. 26-28, pupa: 26, antenna and frontal setae; 27, tergites II-V; 28, anal spur on VIII. 29-33, larva: 29, antenna; 30, premandible; 31, mandible; 32, mentum; 33, lateral body seta.

NOTES

The South African pupa is very similar to that described by Lehmann (1979) notably in the wide point patches on tergites II & III.

Habitat preferences: the larvae were found among stones in very rapid currents in upper mountain streams; they seemed to be better adapted to faster currents than other species of *Rheotanytarsus*. The larval cases are similar to those of other species of the genus but the arm-like extensions of the cases, that support the silk strands, are comparatively much shorter.

Distribution: Ethiopian Highlands, the Kivu district mountains of the Congo (ex-Zaire) and KwaZulu-Natal and Eastern Cape Province (Drakensberg Mountains), South Africa.

Tanytarsus awashensis sp. nov.

(Figs 34-37)

Material examined: this description is based on two drowned and damaged specimens.

ADULT MALE (N = 2 mounted)

Close to generic definition of Cranston et al. (1989).

Wing length: 0.98-1.17 mm.

Colour: head with palps and antennae light brown; thorax and legs light brown, vittae, preepisternum and postnotum brown, abdomen light brown with no obvious markings.

Head: AR 0.71-0.76; frontal tubercles about five times as long as the width of the base; palps (Fig. 34): 195 μm long; segments measuring 16, 31, 40, 46, 62 μm (rather short); two subapical sensillae on segment 3.

Thorax: no scutal tubercle; setation: lateral antepronotals nil, dorsocentrals 6, posterior prealars 1, scutellars 2 per side.

Wings: setae in the apical third of r_{4+5} and m_{1+2}. Wings were in too poor a condition to determine the setation of veins.

Legs: scale of fore femur with long straight point; combs of other legs all with spurs. Tarsi were missing in the specimens, so are not described.

Hypopygium (Figs 35, 36 & 37): anal tergite bands almost transverse and not meeting; anal point with setae but no spine patches, downturned; superior volsella broad, almost square with short beak; digitus reduced; median volsellae short, brush-shaped and meeting centrally (Fig. 36); inferior volsella parallel- sided; apodemes as in Fig. 37.

SPECIMENS EXAMINED

2 ♂♂ found drowned in Lake Busata, a freshwater lake near Awash railway station, Ethiopia 8°05'N 40° 30'E, xi 84, both the holotype and paratype on the slide ETC.67A (the holotype being the specimen near the label); collector ADH (in ZSM).

NOTES

Habitat preference: must have bred in the Lake Busata as there was no other water nearby.

Distribution: Ethiopian Rift Valley.

General note on systematics: T. awashensis is distinguished from all other known African species of *Tanytarsus* (Freeman 1958; Ekrem 2001) and all the Palaearctic species described by Reiss & Fittkau (1971), by the combination of anal point with no spine patches; almost square superior volsella with a short beak and reduced digitus and short, brush-shaped median volsellae that meet centrally. Segment 5 of the labial palps is short. Following the key in Ekrem (2001), *T awashensis* reaches couplet 7 but differs markedly from the two species keyed there: from *T. pallidulus* Freeman in the shape of the superior volsella (not roughly oval) and its median volsella (not rounded) (Freeman 1958), and from *T. atrocinctus* Goetghebuer, which has an L-shaped superior volsella, a distinctly rounded median volsella and an almost club-shaped inferior volsella (Freeman 1958).

Etymology: from the Awash River, Ethiopia.

Tanytarsus flumineus sp. nov.

(Figs 38-43)

ADULT MALE (N= 4 mounted)

Close to generic definition of Cranston et al. (1989).

Body length: 2.7 mm.

Wing length: 1.8 mm.

Colour: whole body yellowish when preserved in alcohol

Head: AR 0.52-0.61; eyes with narrow dorsal extension; no frontal tubercles; head setation with seven verticals; palp segments measuring 30, 33, 96, 105, 192 μm, no subapical sensilla on segment 3.

Thorax: no scutal tubercle; setation: lateral antepronotals nil, dorsocentrals 9 uniserial, posterior prealars 1, scutellars 4 per side.

Wings: no anal lobe; membrane setae dense around wing tip from costa into m_{3+4}, sparser over most of the rest of the wing; vein seta: brachiolum 1, R 22, R_1 36, R_{4+5} 50, numerous on other veins.

Legs: tarsi are not described as most were missing from the material available; spur on foretibia short and curved. LR mid 0.7; sensilla chaetica on tarsomere 1, midleg 6.

Hypopygium (Figs 38, 39, 40, 41 & 42): anal tergite bands not meeting; few small median anal setae; anal point downturned with large crests with long spicules between (Fig. 39) with a few apical anal setae on either side; superior volsella short with at least 20 dorsal setae and a patch of microtrichia at lateral base; protruding digitus with no seta, but with a patch of microtrichia on its base (Fig. 40),

median volsella (Fig. 41) broad and long with short setae; apodemes as in Fig. 42.

ADULT FEMALE (n=1 mounted)

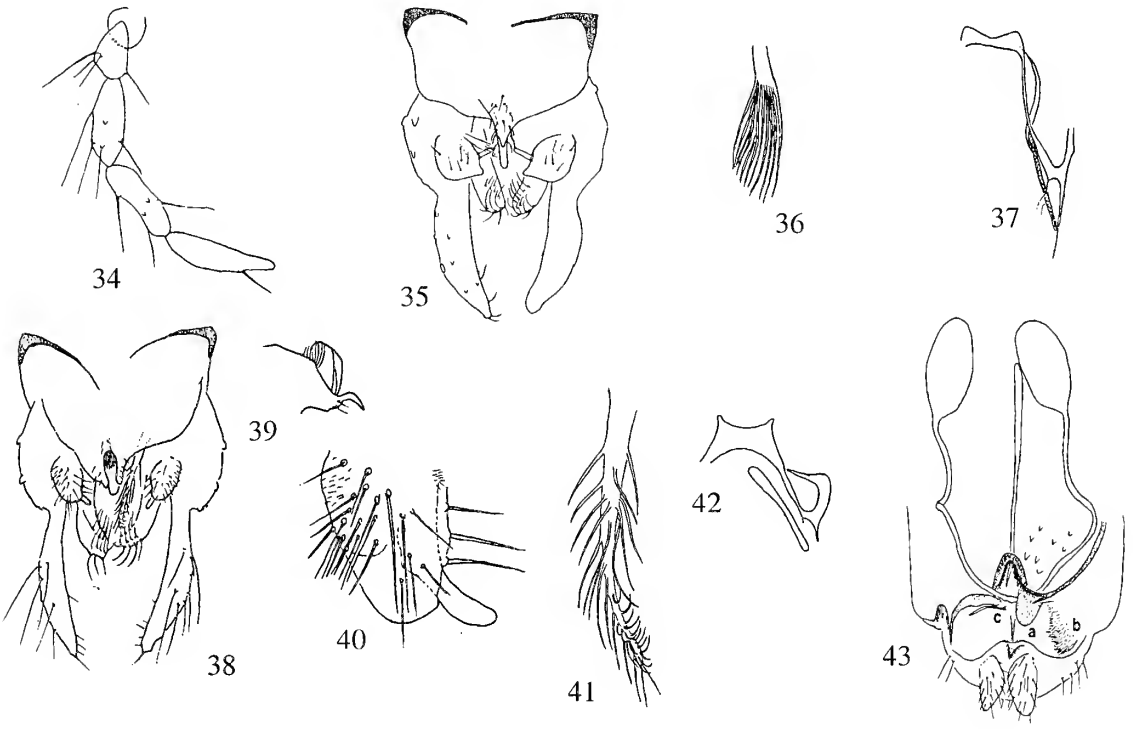
Body length: 2.0 mm.
Wing length: 1.4 mm.
Colour: similar to male.
Head: AR 0.3. No frontal tubercles, eyes like male. Setation: verticals 7. Palp segments 30, 36, 99, segments 4 and 5 missing. No subapical sensory sensilla on segment 3.
Thorax: setation: lateral antepronotals nil, dorsocentrals 11, posterior prealars 1, scutellars 2.
Wings: membrane setae similar to male. Vein setation: R 13, R_1 28, R_{4+5} 55.
Legs: fore tibia with scale and spur like male. All tarsi missing from the available specimen so not described here.
Genitalia (Fig. 43): S VIII forming a small floor under anterior part of the vagina; gonopophysis VIII divided into rounded dorsomesal lobe (Fig. 43a), large ventrolateral lobe (Fig. 43b) and small apodeme lobe (Fig. 43c); gonocoxapodemes narrow and light in colour and joined; coxosternapodemes broad and light in colour; notum long; gonocoxite IX closely applied to body with two to four setae; segment X without setae; postgenital plate triangular; cerci small (48μm); seminal capsules ovoid, large (63μm); seminal ducts with curves, central portion glandular, with common opening.

SPECIMENS EXAMINED

10 ♂♂ and 1 ♀ from Little Mooi River, KwaZulu-Natal, 29°13'S 29°53'E, 4. iv. 95, light trap (Cat. MOI 73AC, AD 1-4); (♂ holotype MOI 73 AD, ♂ paratype MOI 73 AD 3; ♀ paratype MOI 73 AD 4). 1 ♂ Bushmans River above waterfall, 28°46'S 30°10'E, 17 viii 99, (cat. BUS 48L (3)); collectors F.C. de Moor and team (in AM).

NOTES

Diagnostic features are the very large crests and long spicules between on the male hypopygium that distinguish this species from all other species in the genus described by Freeman (1958), Reiss & Fittkau (1971) and Ekrem (2001). This species does not fit in with features described in Ekrem's key apart from the main division in couplet 1 and the division in couplet 8 that leads to the group without a seta on the digitus. The female genitalia differ from those described for the genus by Sæther (1977) as the floor under the anterior part of the vagina is much smaller than he describes, also the species he examined had a simple gonopophysis VIII not divided into three parts as in this species. In discussing the genus he notes: "There are several sharp differences between the female genitalia of the species examined", so the female genitalia do seem to be very variable in this genus.
Etymology: *'flumineus'* Latin (Ovid) riverine.



Figs 34-43. *Tanytarsus* spp. **34-37**, *Tanytarsus awashensis,* adult male: 34, maxillary palp; 35, hypopygium; 36, median volsella; 37, apodemes. **38-43**, *Tanytarsus flumineus*. 38-42, adult male: 38, hypopygium; 39, anal point, lateral; 40, superior volsella; 41, median volsella; 42, apodemes. 43, adult female, genitalia.

Habitat prefereuces: the adults were caught alongside rivers so, presumably, the larvae lived there.
Distributiou: known only from KwaZulu-Natal, South Africa.

Tanytarsus zimbabwensis sp. nov.

(Figs 44-46)

(Note: the specimen was originally pinned).

ADULT MALE (N = 1 mounted)

Close to generic definition of Cranston et al. (1989).
Body length: 1.7 mm.
Colour: pinned specimen with head light brown, thorax light brown, vittae darker, abdomen yellowish.
Wiug leugth: 1.2 mm.
Head: AR 1.0. Eyes with short parallel-sided dorsal extension; no frontal tubercles; palp segments damaged but appear to be normal for the genus.
Thorax setation: lateral antepronotals nil, dorsocentrals 10, posterior prealars 1, scutellars 2.
Wiugs: no anal lobe; setae on membrane: dense patches of setae at tips of r_{4+5} and m_{1+2} with an irregular row in the rest of these cells, dense patch of setae at tip of m_{3+4} and a few in anal cell; vein setation: R 16, R_1 12, R_{4+5} 22, other veins all with setae.
Legs: mid and hind tibia each comb with a short straight spur. (Note: in the specimen examined the forelegs were missing and the other legs in poor condition).
Hypopygiuu (Figs 44, 45 & 46): anal tergite bands separate; seven anal tergite setae and three apical anal tergite setae per side; anal point with no central ridge, crests or spines, bare and rounded at the tip; superior volsella dog's-head shaped with long, protruding digitus; median volsella (Fig. 45) short with lamelliform setae; gonostylus small and narrow. The apodemes are illustrated in Fig. 46.

SPECIMEN EXAMINED

1 ♂ (holotype) bred out in laboratory from stream from granite dome Ngoma Kuriru, Chindomora, Zimbabwe, 17°35'S 31°10'E, 25. ii. 1964. (CCA.96C). Collector ADH (in AM).

NOTES

The following features are of diagnostic importance: the bare anal point with no central ridge, the dog's-head shaped superior volsella; the distinctive median volsella and the small and narrow gonostylus. These distinguish this species from those described in Freeman (1958), Reiss & Fittkau (1971) and Ekrem (2001). This species keys out to couplet 6 in Ekrem's key but the distinctive structures of the superior and media volsellae and the narrow gonostylus easily separate it from the species keyed there – *T. atouarius* Kieffer and *T. pallidissiuus* Kieffer.
Habitat Prefereuces: the reared larvae were collected from stones in rapids in a small, swift-flowing stream.
Distributiou: known only from Zimbabwe.

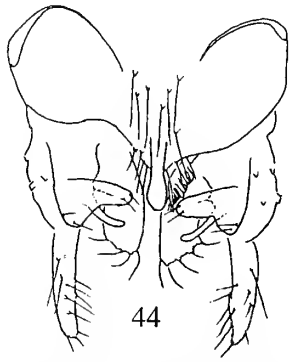
Virgatanytarsus aboensis sp. nov.

(Figs 47-50)

Material exauiued: this description is based on males from Ethiopia and one from Zimbabwe. Descriptions of the Zimbabwean specimen are given in brackets.

ADULT MALE (N = 11 mounted)

Close to generic definition of Cranston et al. (1989).
Body length. Ethiopia (N=9): 4.25-3.65 mm; Zimbabwe (N=2): 3.1 and 2.7 mm.
Wiug leugth. Ethiopia (N=9): 2.9-2.5 mm; Zimbabwe (N=2): 2.0 and 1.9 mm.
Colour: head with antennae and palps brown; thorax brown, vittae, preepisternum and postnotum dark brown; wings with brownish tinge; legs brown; abdomen and hypopygium brown.
Head: AR 0.88-0.98 (0.90); frontal tubercles present; palp segments measuring 34, 53, 136, 140, 248 (34, 50, 124, 146, 248) μm; two subapical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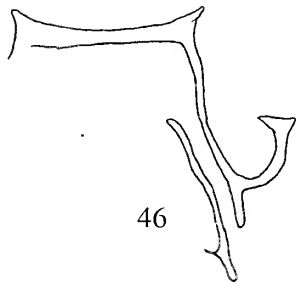
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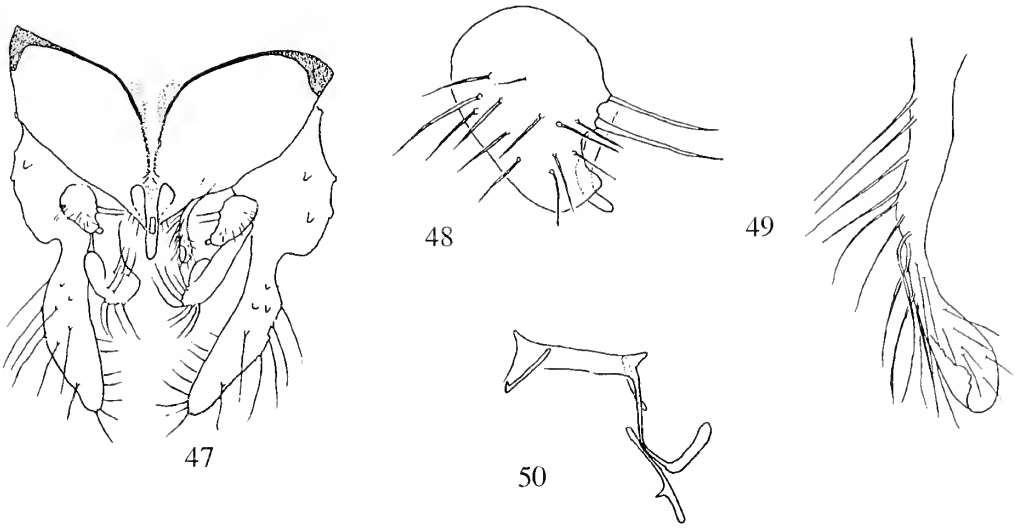
Figs 44-46. *Tanytarsus zimbabwensis,* adult male: 44, hypopygium; 45, median volsella; 46, apodemes.



Figs 47-50. *Virgatanytarsus aboensis*, adult male: 47, hypopygium; 48, superior volsella; 49, median volsella; 50, apodemes.

sensillae on segment 3.

Thorax: no scutal tubercle; setation: lateral antepronotals nil, dorsocentrals 9-10, posterior prealars 1, scutellars 5 per side.

Wings: most of the wing extensively covered by setae, denser distally, but only present distally in cu and an. Setation of veins: brachiolum 1, R 28, R_1 25, R_{4+5} 25; other veins with setae except subcosta.

Legs: LR fore 2.3-2.6; mid 0.6; hind 0.64-0.74. Sensilla chaetica on tarsomere 1, on midleg 5-7, on hindleg nil. Table 3 shows leg measurements and ratios.

Hypopygium (Figs 47, 48, 49, 50): anal tergite bands separate but appear to continue posteriorly as darkly pigmented stripes that almost join just before the base of the anal point that has a short reflexed rod between the crests; superior volsella (Fig. 48) with at least 15 dorsal setae and digitus protruding in most specimens; median volsella (Fig. 49) with tip wide and flattened, edges tending to distort upwards, lamellae pointed; inferior volsella with a large, rather flat process (crista dorsalis?) without microtrichia, extending dorsomedially or dorsally. The apodemes are shown in Fig. 50, the pair of rods immediately ventral to the sternapodeme are present in all mounted specimens and may be part of the phallapodeme.

Etymology: *V. aboensis* from the Abo River in Addis Ababa and Ethiopia.

SPECIMENS EXAMINED

1 ♂ Addis Ababa, Ethiopia, 09°00'N 38°47'E. (ETC.5J) xi. 82; 6 ♂♂ from Abo River, Addis Ababa, Ethiopia, 09°04'N 38°47'E (ETC. 42F & G) 8 ix 84, 1 (ETC.49H) v.85, 2 (ETC. 51M1 & M2) v.85, 1 (ETC. 60J) ix. 85, 1 (ETC. 61C) ix. 85; 1 ♂ from Kosso River Ethiopia, 09°43'N 39°39'E, (ETC. 26K) 12 i 84; 3 ♂♂ from Chindomora, Zimbabwe, 17°36'S 31°08'E (CCA. 24C & E, 96G) 10. ii.63 (collector ADH). All deposited in ZSM except CCA. 96G (that is in AM).

Other material: ♂♂ from Tugela Estates below Blauwkranz River confluence, upstream of Bushmans River, KwaZulu-Natal, 28°45'S 30°09'E (TUG127 AF6-10) 18 viii 99 (collectors F.C. de Moor and team). This material was in poor condition and was not used for description; deposited in AM. Holotype ♂ ETC. 51M1; paratype ♂ ETC. 42G.

Table 3: *Virgatanytarsus aboensis*, leg measurements in μm and ratios

		fe	ti	ta_1	ta_2	ta_3	ta_4	ta_5	LR	BV	SV
Ethiopian specimen	p_1	750	500	1200	500	400	350	175	2.4	0.96	1.6
	p_2	900	700	450	250	200	100	75	0.64	0.3	3.38
	p_3	1050	950	600	350	300	250	50	0.63	0.3	2.6
Zimbabwean specimen	p_1	550	450	1000	450	400	250	150	2.2	1.0	1.6
	p_2	750	650	500	250	175	100	75	0.58	0.26	3.0
	p_3	850	850	625	350	300	200	75	0.74	0.37	2.5

LEGEND: fe = femur; ti= tibia; ta_1, ta_2, ta_3, ta_4, ta_5= tarsomeres 1-5; LR = leg ratio (length of tarsomere 1: length of tibia); BV = 'Beinverhältnisse' = combined length of femur, tibia and tarsomere 1 divided by length of tarsomeres 2 to 5; SV='Schenkel-Schicne Verhältnis' = ratio of femur plus tibia to tarsomere 1.

NOTES

Differential diagnosis: anal point with short reflexed rod between crests, inferior volsella with a large flat process, without microtrichia, extending dorsomedially or dorsally. Only two further species were known previously from sub-Saharan Africa: *Virgatanytarsus arduensis* Goetghebuer and *V. nigricornis* Goetghebuer. The first is widespread in the tropics and the second in the tropics south to Kwa-Zulu-Natal. *V. aboensis* is easily distinguished from these by the shape of the inferior volsella.

The specimens from Zimbabwe came from a pristine mountain stream running off a large granite inselberg and the Ethiopian specimens came from a mountain stream immediately above Addis Ababa that was somewhat organically enriched; this could account for the larger specimens from that stream. The KwaZulu-Natal specimens were drowned in the river and unsuitable for measurements.

Habitat Preferences: this species appears to breed in mountain streams, even in stony runs.

Distribution: Ethiopian Highlands, Zimbabwe and KwaZulu-Natal.

ACKNOWLEDGEMENTS

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SHORT COMMUNICATION

METRIOCNEMUS CAPICOLA, A REPLACEMENT NAME FOR *METRIOCNEMUS CAPENSIS* HARRISON 2002

AD Harrison

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Harrison (2002) named a new species of *Metriocnemus*, *'M. capensis'*, overlooking the fact that the name was preoccupied. Freeman & Cranston (1980) listed another species, *Parametriocnemus capensis* (Freeman), but Freeman (1954) originally named that species *Metriocnemus capensis*. Harrison's species name is therefore invalid and must be considered a homonym, *Metriocnemis capensis* Harrison **homonym**. A replacement name, *Metriocnemus capicola* **nomen novum** is proposed for Harrison's (2002) species.

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A PRELIMINARY INVESTIGATION INTO THE INFLUENCE OF TURBULENCE ON LARVAL FEEDING IN TWO SPECIES OF BLACKFLY, *SIMULIUM CHUTTERI* LEWIS AND *SIMULIUM NIGRITARSE* COQUILLETT (DIPTERA, SIMULIIDAE), FROM THE GREAT FISH RIVER, SOUTH AFRICA

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ABSTRACT

Since 1977, larvae of the pest species *Simulium chutteri* Lewis have largely replaced *Simulium nigritarse* Coquillett as the dominant species of blackfly in the Great Fish River in the eastern Cape. This is thought to be due to a change from intermittent to continuous water flow, since the completion of an interbasin water transfer scheme from the Orange River to the Great Fish River. Changes in turbulence of the flow may be one of the factors responsible for this shift in species composition, and in this study, the effect of turbulence on the feeding of larvae was investigated under laboratory conditions. Turbulence was measured as Reynold's number, with larvae feeding on algae under different conditions of turbulence created in glass tubes. Feeding activity was measured by measuring algal (*Chlorella*) cell counts and chlorophyll *a* concentrations from gut contents after feeding, and by cephalic fan activity. The results indicate that, under conditions of higher turbulence, *S. chutteri* feeds more efficiently than does *S. nigritarse.*

Keywords: blackfly larvae, turbulence, flow rates, Reynold's number, feeding behaviour

INTRODUCTION

Simulium chutteri Lewis is well known in its adult stage as a pest, as the females imbibe blood from livestock (Chutter 1968). Car & de Moor (1984) quote farmers reporting losses in stock production and occasional deaths in young animals through excessive blood feeding by this species. Studies by Chutter (1972) and Scott et al. (1972) showed that between 1970 to 1971, *Simulium nigritarse* Coquillett and *Simulium adersi* Pomeroy were the dominant blackfly species in the Great Fish River at Carlisle Bridge (33°04'55"S 26°13' 45"E), although *S. chutteri* was present in low numbers (O'Keeffe & de Moor 1988). Since 1977, the Great Fish River and its surroundings (Fig. 1) have been plagued by increasing numbers of *S. chutteri*, which replaced *S. nigritarse* and *S. adersi* as the dominant blackfly species (de Moor & O'Keeffe 1987). The change in species composition occurred after the completion (in 1977) of an interbasin transfer scheme whereby water was channelled from the Orange River to the Great Fish River. The water transfer resulted in a change in the Great Fish River from intermittent flow to perennial flow (O'Keeffe & de Moor 1988).

A similar change in species composition has been reported with damming of rivers in northern Alberta and Saskatchewan, whereby *Simulium luggeri* Nicholson and Mickel replaced *Simulium articum* Malloch as the dominant species, after changes in flow regimes, following impoundment (Wood 1985). Coetzee (1982) found that in the upper reaches of the Great Fish River, upstream of the outlet of Orange River water, *S. nigritarse* larvae were still more abundant than those of *S. chutteri.* An unpublished survey carried out by the author and colleagues during 1985 indicated that *S. nigritarse* was a dominant macroinvertebrate species in the upper reaches of the Great Fish River. Although regulated by numerous small farm dams, the flow in these reaches continued to be seasonal. More recent observations (pers. obs. and communication from local farmers) indicate that water in these reaches remains clear for most of the year. Conditions may, however, become turbid during spates after rainfall. The water in the lower reaches is generally more turbid. O'Keeffe & de Moor (1988) investigated flow patterns and water chemistry for the Great Fish River, both upstream and downstream of the outlet, prior to, and after, the introduction of Orange River water. They found that there had been marked changes in flow regimes and water chemistry below the outlet, compared to the situation prior to the introduction of Orange River water.

Downstream of the Orange River water outlet, relative abundances of both *S. nigritarse* and *S. adersi* declined, while those of *S. chutteri* increased greatly subsequent to the inflow of Orange River water (O'Keeffe & de Moor 1988). Current velocity and water volume are known to be important in controlling habitat suitability for various *Simulium* species (de Moor 1994). *S. chutteri* is normally found in fast-flowing, large rivers, while *S. nigritarse* and *S. adersi* are generally found in small streams to medium sized rivers (de Moor 1989; Palmer & de Moor 1998). Palmer & de Moor (1998) have also indicated that, although *S. chutteri* has been recorded in low numbers from several small, clear rivers in the eastern Cape, it only achieves high

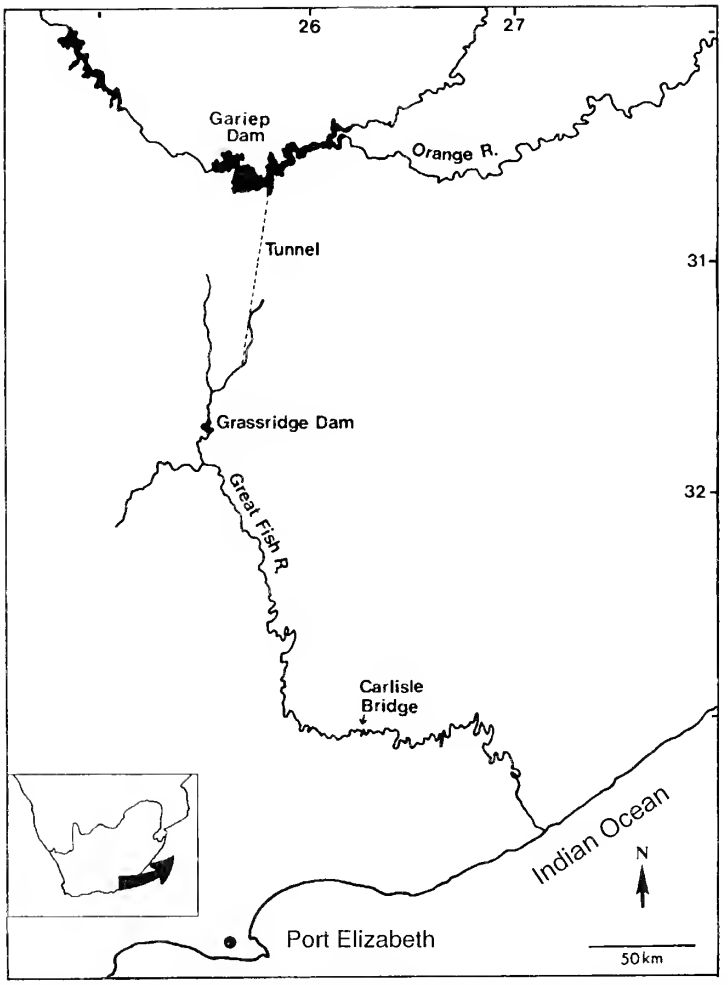


Fig. 1: The Great Fish River, indicating the position of Carsile Bridge. The dashed line represents the tunnel connecting the Orange and Great Fish river systems.

population densities in large, turbid rivers, such as the Vaal River. During a period of low flow following a severe drought (from 1980-1982), when the turbidity in the lower Vaal river was noted to be unusually low, the normally-dominant simuliid species, *S. chutteri*, was replaced by *S. hargreavesi* (Car & de Moor 1984; de Moor 1994). The avoidance of clear water by *S. chutteri* is further confirmed by the observation by Palmer & O'Keeffe (1990) that numbers of *S. chutteri* drop significantly downstream of impoundments where clearer water is released into normally-turbid rivers.

The effect of changing flow conditions on feeding activity has been documented for several simuliid species. For example, distinct differences in fan adduction activity relating to increased current speed have been shown for nine European *Simulium* species (Schröder 1980, 1988). Studies on feeding behaviour, rates of ingestion and selectivity of food particle size have also been carried out for several Nearctic species, for example, Kurtak (1978), Craig & Chance (1982), Ciborowski & Craig (1989), Hart & Latta (1986), Hart et al. (1991). For this study, laboratory experiments were set up to investigate the effects of increasing turbulence, defined by Reynolds number, on the feeding ability of *S. chutteri* and *S. nigritarse*.

MATERIALS AND METHODS

The calculation of Reynold's number

Reynolds number is the ratio of inertial forces to viscous forces in liquids (Smith 1975; Vogel 1981) and defines the properties of fluid motion. Low Reynolds numbers (below 500) indicate laminar flow, while Reynolds numbers approaching 2000 or more indicate turbulent flow.

Reynold's number (*Re*) is calculated according to the equation:

$$Re = \frac{Ul\,\rho}{\mu} = \frac{Ul}{\upsilon}$$

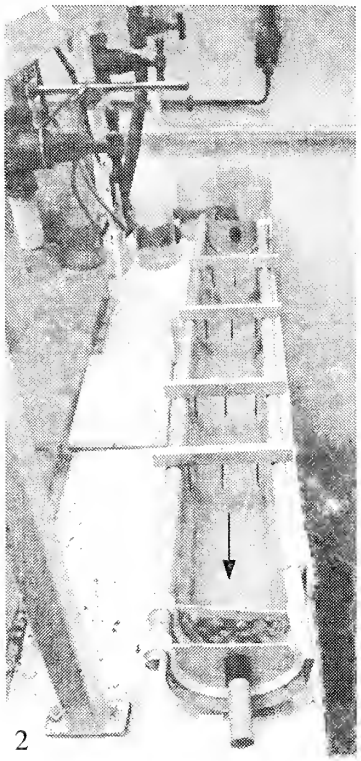
where:
U is the mean velocity (cm s^{-1})
l is the tube diameter (cm)
ρ is the density of water at a specified temperature
μ is the dynamic viscosity of water
υ is the kinematic viscosity of water

Collection of samples and measurement of larvae

Larvae were collected from the Great Fish River at Carlisle Bridge (Fig. 1), during late May (winter) and again in late October into early November (summer) for both species. As it was not possible to do all the experiments at the same time, summer populations of larvae of both species were used for the haemocytometer-analysed results and for fan adduction counts, while winter populations were used for those analysed by fluorometry (see analysis of feeding below). As final instar larvae do not feed (de Moor 1982a), sixth instar larvae were selected for all experiments. These differ from final instar larvae in that the respiratory histoblasts are not yet fully developed and the cervical sclerites are not yet fully separated from the preocciput (de Moor 1982 c & b). Recently-moulted larvae (those with pale yellow head capsules) were used, as the rate of feeding may differ in older larvae of the same instar (de Moor 1982b). Larvae of each species from both populations were measured to compare sizes, in case one group should be bigger than the other, which could also influence feeding. The total body lengths of 75 typical sixth instar larvae of each species were measured using a dissecting microscope with a graticule. Differences in winter and summer populations have been previously documented (de Moor 1982a, 1982b), and can be explained in terms of reduced water temperatures resulting in slower growth rates, longer development periods and, hence, the development of larger larvae. No attempts were made to investigate sexual difference between larvae in these experiments, and although de Moor (1982a) found that females of later stage larvae were larger than the equivalent males, Elsen et al. (1978) have indicated that sex has no influence on larval feeding in *S. dammosum*.

Acclimatization

Before initiating the experiment, the larval alimentary tracts had to be cleared of food. A section of plastic guttering, connected to a water inlet at one end and with an outlet at the other end (Fig. 2), was set up as a channel to allow gut clearance. A continual flow of clean water could pass through this channel when required. Strips of hard, clear plastic measuring 5 mm by 100 mm, with cotton loops at each end, were suspended lengthwise down the channel, into the flowing water, from wooden rods, which rested across the channel (Fig. 3). Larvae collected from the field were placed in the channel, and some of the larvae attached themselves to these plastic strips, which would later be transferred, bearing larvae, into the experimental tubes. The larvae were retained in the channel in algae-free water to clear their alimentary tracts before starting the feeding experiments. The gut retention time for *Simulium* species has been shown to be highly variable, ranging from 0.5



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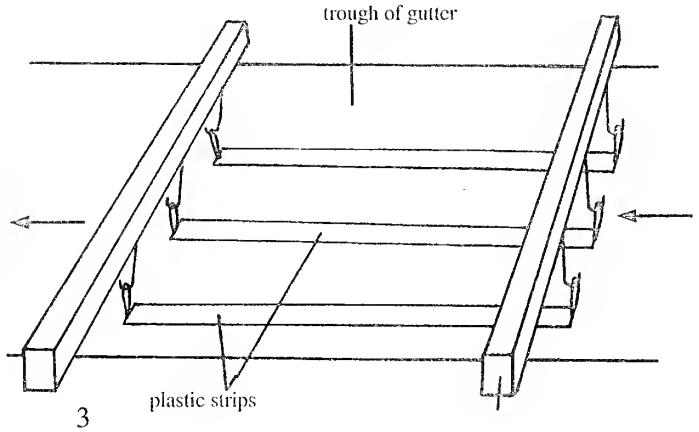

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Figs 2 & 3. Apparatus used for gut clearance of blackfly larvae. **2**, photograph of the apparatus showing diagonal bars from which plastic strips were suspended. **3**, Diagrammatic representation of a section of the rigid plastic strips on which larvae settled. Arrows indicate the direction of water flow.

hours to 4 hours (Kurtak 1978; Ladle & Hansford 1981; Fredeen 1964; Chance 1970). Preliminary investigations were carried out to establish the required clearance times for *S. chutteri* and *S. nigritarse*. This was done by removing larvae from the channel every 30 minutes and investigating the contents of the alimentary tracts on a slide under a microscope. These tests revealed that 2 hours was a sufficient time period for gut clearance in both *S. chutteri* and *S. nigritarse*. Quantitative measurements were not done for this.

The larvae used for these experiments were acclimatized to 21°C in the laboratory, irrespective of season collected, and the water temperature in the experimental tank was maintained at 21°C. Winter water temperatures would have been cooler, but it was decided to approximate summer temperatures for the experiments as feeding may have been reduced and would, therefore, be harder to measure at lower water temperatures.

Apparatus and Experimental Procedure

The experimental apparatus for this investigation was modified after Noble (1970). It consisted of a glass tank with a capacity of 15*l*, filled with a suspension of *Chlorella*, in which a system of interlocking, open-ended glass tubes (Figs 4 & 5A) was submerged. The upper tube was wider (internal diameter 25 mm) than the lower tube (internal diameter 10 mm), since tubes with smaller diameters produce more turbulent conditions.

The upper tube was attached to a water pump, which could be adjusted to vary flow rates. The flow of water from the pump through the tubes was controlled using a rheostat. Velocities at different rheostat settings were determined by introducing drops of 1.25M potassium permanganate solution (used as an indicator dye) through a port on the upper side of the tube near the mouth (Fig. 5A), into the middle of the stream of water passing through the tube. The nucleus of the droplet moved forward, with a thin trace of colour trailing behind. The progress of the droplet was timed over a fixed distance. This was repeated twenty times for each rheostat setting to estimate the velocity so that Reynold's number could be calculated.

Laboratory tests involved a three-step process: field collection and measurement of larvae; laboratory acclimatization, and feeding experiments.

Feeding tests

After clearing the alimentary tracts of food imbibed in the natural river environment (as described above), the plastic strips, bearing larvae, were carefully transferred to the centre of one of the glass tubes in the tank (Fig. 4). The strips were positioned longitudinally down the center of a tube and attached by the cotton loops to hooks within the tube (Fig. 5B). In this way, different groups of larvae could be subjected to one of six different conditions of turbulence (i.e. six values for Reynold's number). A maximum of about 10 larvae were introduced to a tube each time, since it was found that, at higher densities, feeding of individual larvae was often interrupted by movements of neighbouring larvae.

Once the larvae had settled in the tubes (2 minutes acclimatization allowed each time), the flow

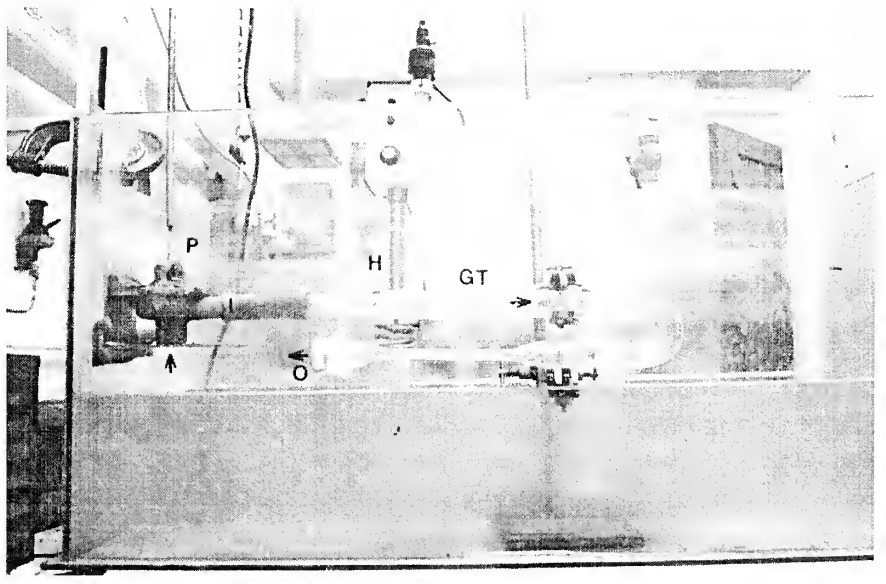

Fig. 4. The experimental apparatus within an aquarium (with water level lowered to show inner apparatus more clearly) showing tubes in which turbulence can be varied. LEGEND: GT = glass tubes; H = heat stirrer; I = inlet; O = outlet; P = part of pump.

was switched on, creating the required level of turbulence. Feeding was allowed to continue for 10 minutes before switching off the flow and removing the larvae from the tube. Larvae were placed in labelled vials containing 5% formalin, or in cold insect saline, and immediately refrigerated, depending on the subsequent method of analysis of algal content (see below for a description of these methods).

Oxygen concentration of the water in the tank was frequently determined using the Winkler method, to confirm that it was never in short supply. Because the water was rich in algae, Alsterberg's modification of the Winkler titration for water rich in organic matter was used (in Mackereth et al. 1978).

ANALYSIS OF FEEDING

Three methods were used to compare feeding in the two species. Larval gut contents (equivalent to the amount of algae ingested) were estimated using haemocytometer counts of algal cells, and fluorometric measurements of chlorophyll *a*. A third estimate involved counting the number of adductions of a blackfly's cephalic fans over a fixed period of time, to see if the behavioural response was affected by changing turbulence.

Haemocytometer analysis

After feeding, the larvae were immediately preserved in 5% formalin for later dissection.

The entire gut content of a larva was dissected and dispersed in 1.00 ml of distilled water and subsamples of this were examined under a Neubauer Bright Line Haemocytometer. The haemocytometer was standardized to hold exactly 0.0009 ml of sample, and all of the algal cells present in this volume were counted. Five separate counts of algal cells were recorded for each 1 ml sample (i.e. for each larva), and this was done for the gut contents of 15 larvae at each of the six levels of turbulence (*Re* values). The mean number of cells per 0.0009 ml sample from the gut contents was taken to represent the amount ingested for each larva, and these values were compared for the two species. Comparisons between the feeding of the two species was done using a t-test at each level of turbulence.

A control experiment was run to see if the same quantities and size ranges of cells were available to both species. Algal cell counts and size measurements were done on water samples taken directly from the 15*l* tank prior to each set of experiments. Comparisons of the size of algae in the tank to the size ingested by the larvae of each species were analysed using t-tests.

Fluorometry analysis

Immediately after feeding, larvae were placed in a vial containing cold insect saline and refrigerated at 4°C. Refrigeration was chosen rather than storage in a preservative so that the chlorophyll *a*

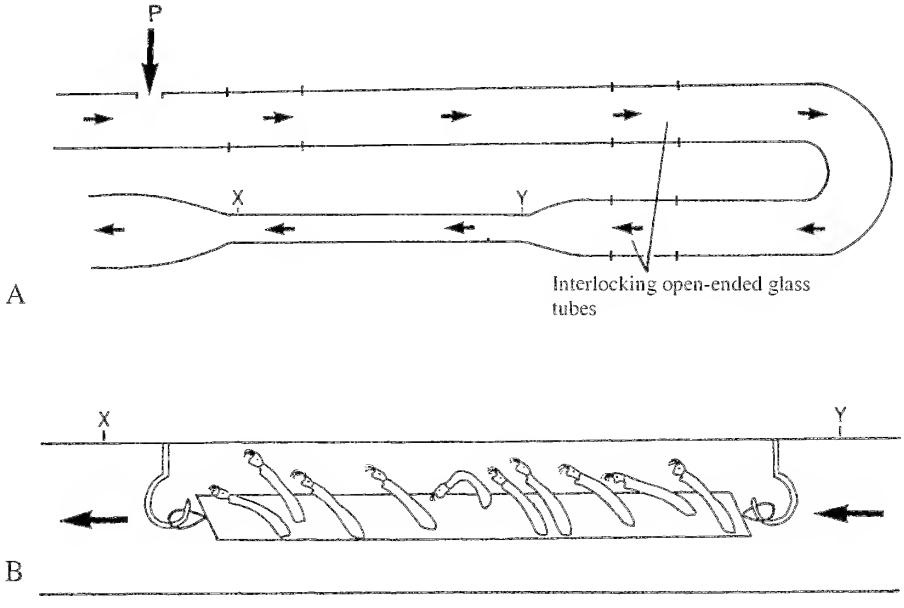

Fig. 5. A. Diagrammatic representation of interlocking, open-ended glass tubes used to measure turbulence. Drops of potassium permanganate are introduced through a small aperture (P) to estimate current speeds (and hence, turbulence). **B**. Detail of section X-Y (from A) illustrating larvae resting on plastic strips. Arrows indicate direction of water flow.

would not be chemically altered. Dissection was undertaken as soon as possible thereafter. Alimentary tracts were dissected from ten larvae for each of the six turbulence levels, gut contents were then pooled from each group of ten and placed in a vial containing 10 ml of 90% acetone. This was carried out three times for each of the six turbulence levels. Chlorophyll *a* concentration was measured using a Turner Fluorometer model 111. This was set at its greatest sensitivity and calibrated using standard chlorophyll *a* of known concentrations and 90% acetone as a blank. The feeding of the two species at different turbulence levels was compared using a t-test.

A control test of the chlorophyll *a* concentration of the water in the tank was measured at the onset of each set of experiments to check that conditions remained constant.

Observations of cephalic fan adductions

In blackfly larvae, particles from flowing water are trapped in the cephalic fans and transferred to the mouth by means of fan adductions, combined with a series of movements of other mouthparts. Fan adduction rate therefore gives an indication of the feeding rate (Craig 1977; Craig & Chance 1982; Hart & Latta 1986; Currie & Craig 1987; Palmer & Craig 2000). The number of cephalic fan adductions per minute were noted for three individual larvae at each value of Reynold's number for both *S. chutteri* and *S. nigritarse*. Craig & Chance (1982) found that only the primary fans of simuliids are directly involved with capturing particles from the water, and only these fans were observed.

While the animals were in the experimental tubes, each individual was observed three times, for a minute each time. A dissecting microscope was set up against the tank to facilitate observations. The contractions of only one fan were counted for each larva. Comparisons between the fan adduction rates of the two species was done using a t-test for each turbulence level.

RESULTS

Length measurements

Body length measurements of 75 larvae at the chosen stage of development (sixth instar) show that there were no significant differences between the sizes of larvae within each species ($p<0.05$), and that the sixth instar larvae of the two species had a similar size range. The winter populations of both species were, however, significantly ($p<0.005$) larger than the summer populations. Information on the sizes of larvae in the two populations is given below.

SUMMER POPULATIONS

S. chutteri

range = 3.15-4.35 mm; mean = 3.65 mm ± 0.34.

S. nigritarse

range = 3.22-4.04 mm; mean = 3.58 ± 0.03.

WINTER POPULATIONS

S. chutteri

range= 4.72-6.20 mm; mean = 5.36 ± 0.43.

S. nigritarse

range = 4.49-6.15 mm; mean = 5.27 ± 0.52.

Feeding experiments

Measurements of algal cell sizes revealed that similar sized cells were available in the experimental tank for both species at the onset of experiments using haemocytometer measurements (Table 1). Wotton (1973) found a significant positive correlation between particle sizes in simuliid guts and in stream water, showing feeding to be unselective, and Chance (1970), despite finding selective feeding in the laboratory, found that in the field, feeding was unselective. For both *S. chutteri* and *S. nigritarse*, the mean size of the cells ingested was, however, found to be smaller than the mean size of the cells available, indicating that both species selectively ingested a slightly smaller range of cells sizes than the mean range available (Tables 1 & 2).

A 10-minute feeding period was found to be long enough to allow a measurable amount of ingestion. Haemocytometric analysis of the gut contents of larvae which fed under different conditions of

Table 1. Size ranges of algal cells available in tank prior to feeding experiment. Standard deviations are indicated in parenthesis (n = 35)

	Size range (µm)	Mean (µm)
S. chutteri	200-1300 (260)	683
S. nigritarse	230-1100 (220)	550

Table 2. Size ranges of algal cells ingested at each turbulence level (Reynold's number) for the haemocytometry experiments. Standard deviations indicated in parenthesis (n = 15)

Turbulence (*Re*)	*S. chutteri*		*S. nigritarse*	
	Range ingested (µm)	Mean (µm)	Range ingested (µm)	Mean (µm)
174	230-1224 (245)	474	230-816 (183)	447
481	204-1097 (292)	592	230-1020 (229)	492
752	230-1020 (193)	415	230-1071 (260)	442
1487	230-995 (196)	413	230-1020 (223)	473
1638	230-893 (201)	459	230-1097 (256)	502
2004	240-836 (188)	408	230-791 (185)	451

turbulence showed a significant increase in the number of cells ingested by *S. chutteri* at higher turbulences (*Re* values of 1638 & 2004). The opposite was seen for *S. nigritarse*, with a decrease in numbers of cells ingested at higher turbulences (Fig. 6A). Comparing the two species using t-tests, highly significant differences at various turbulence levels (at *Re* values of 481, 752, 1487, 1638 and 2004: $p<0.005$) were observed, while only at Re values of 174 were cell counts not significantly different ($p>0.2$) (Fig. 6A).

For the fluorometric experiments, chlorophyll *a* concentrations in the tank were similar at the onset of experiments with each species (35.9 µg/l in the '*S. chutteri*' tank; 36.3 µg/l in the '*S. nigritarse*' tank). The results from these analyses showed a similar trend to the haemocytometer-measured experiments, but the distinction was less clear (Fig. 6B), and at a turbulence of 1487 *Re*, algal ingestion by *S. nigritarse* actually increased, as opposed to the dramatic drop observed in the haemocytometer counts. A significant difference ($p<0.05$) in chlorophyll *a* levels determined from the gut contents of each species was seen at each turbulence level, although this was greatest at the highest turbulence (*Re*=2004).

Although fan adductions ceased at turbulence values of 2004 *Re* for *S. nigritarse* (Fig. 6C), chlorophyll *a* was measured from the guts of the larvae subjected to this level of turbulence (Fig. 6B). It is possible that some algae were ingested during the 2-minute acclimation period prior to the onset of the experiments. This was not taken into consideration, and was assumed to be the same for all larvae, since they were subjected to similar conditions. Fan adduction observations showed that *S. chutteri* had a higher adduction rate than *S. nigritarse* for all turbulence levels, but this became more pronounced at higher turbulences (Fig. 6C). Significant differences ($p<0.005$) in fan adductions between the two species were observed at all but the lowest turbulences (*Re*=174). In moderately turbulent conditions (*Re*=2004), or conditions approaching high turbulence (*Re*=752, 1487 & 1638), the rhythmic fan adductions of *S. nigritarse*, which characterized feeding at lower turbulences (*Re*=174 & 481), became less regular. The fans of many individuals remained closed throughout the runs at the highest turbulences (*Re*=2004), or flicked quickly without opening properly. Others seemed unable to adduct their fans, which remained continually open. In *S. chutteri* the adduction pattern was little affected by increasing turbulence. These observations suggest that under high turbulent conditions, larvae of *S. nigritarse* were unable to feed properly.

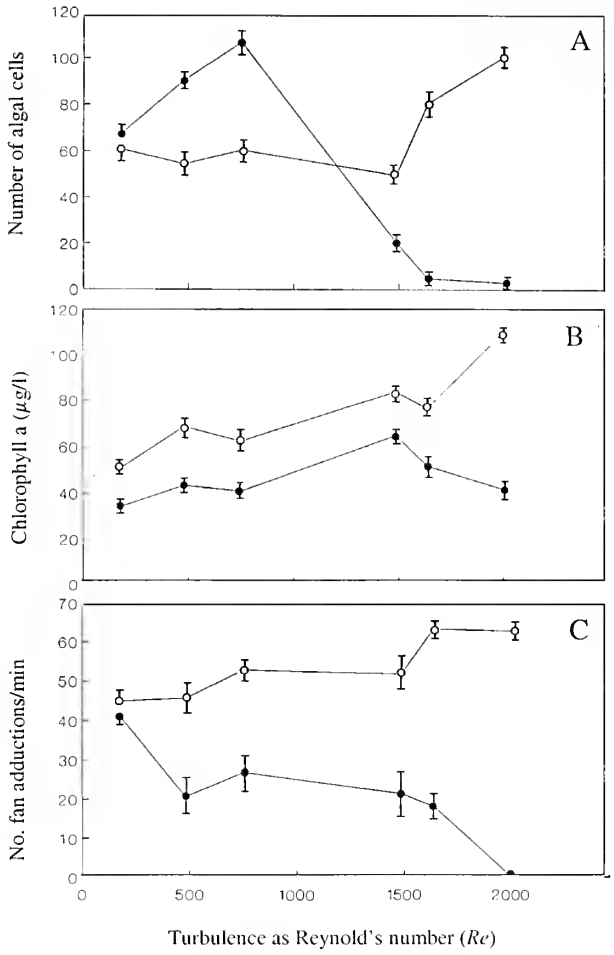

Fig. 6. Results of feeding experiments: (a) Relative numbers of algal cells counted from the gut contents of simuliid larvae; n=10. (b) Levels of chlorophyll *a* measured from the gut contents of simuliid larvae; n=30. (c) Fan adduction rates per minute for simuliid larvae; n=3. Larvae were subjected to flow conditions of increasing turbulence (*Re* values). Standard errors are indicated by vertical lines. ○=*S. chutteri;* ● *S =nigritarse.*

DISCUSSION

A potential problem with interpreting the data obtained during these experiments is that the larvae in the experimental tubes may be responding directly to changes in current velocity rather than to the changes in turbulence. However, since the calculation of Reynold's number takes current velocity into account, the responses measured are in relation to Reynold's number and therefore assumed to be due to changes in turbulence. Another limitation of this experimental work is that higher turbulences, above *Re* values of 2004, could not be attained with the apparatus used. This means that most of the studies fell into the flow range that is transitional between laminar and turbulent flows. In the field, the natural turbulence would be much higher than that measured in these experiments. Finally, an increased number of replicates would have provided better confidence in the statistical analysis, but the time limitations of the project did

not allow this. Despite these shortcomings, the different responses of the two species to changes in turbulence was clearly demonstrated using three different methods. It is recommended that further work be done on the feeding of these two species to corroborate these results.

A number of conditions besides turbulence have changed in the Fish River since 1977, all of which may have influenced the invertebrate community, and which may have played a part in the observed change in species dominance. There have been changes in water chemistry (O'Keeffe & de Moor 1988) and the high turbidity and strong flow conditions associated with high numbers of *S. chutteri* larvae (de Moor 1994) now prevail in the Great Fish River. Certain behavioural responses such as oviposition are known to affect the success of simuliids. de Moor et al. (1986) found that females of *S. chutteri* scatter eggs in slower-flowing water upstream of rapids. The small larvae colonize the slower flowing reaches, while the more mature larvae drift and establish themselves in the rapids, unlike the coexisting species, *S. nigritarse* and *S. adersi*, which restrict themselves to the slower flowing reaches of the river. *Simulium nigritarse* lays its eggs in patches below the water surface on partly submerged stones (Chutter 1972). Oviposition and larval establishment are therefore aspects of the life history of these species that are directly affected by flow.

CONCLUSIONS

Although other factors may influence the invertebrate population structure, the results of this study do indicate that turbulence is one of the factors favouring the change in simuliid species composition in the Great Fish River. After quantifying the effects of increased turbulence on the feeding of *S. chutteri* and *S. nigritarse*, it is not surprising that changes in the community structure have occurred, favouring the pest species *S. chutteri*.

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